Radiation Dose

Results in Brief: 2001 Estimated Doses

Airborne Emissions - The estimated maximum effective dose equivalent at the site fenceline from 2001 airborne emissions (excluding radon) was calculated to be 0.8 mrem, which is 8 percent of the EPA NESHAP 10 mrem annual dose limit.

Direct Radiation - The estimated 2001 effective dose equivalent at an off-site receptor location near the western fenceline of the FEMP was 11.5 mrem.

Dose to the Maximally Exposed Individual - The dose to the maximally exposed individual for 2001 was estimated to be 11.7 mrem at an off-site receptor location near the western fenceline of the FEMP. This is 11.7 percent of the 100 mrem DOE limit.

This chapter provides estimated doses to the public from the air and direct radiation pathways for 2001 as a result of remedial actions taken at the FEMP. EPA NESHAP regulations require the FEMP to demonstrate that its radionuclide airborne emissions are low enough to ensure that no one in the public receives an effective dose of 10 mrem or more in any one year. Moreover, to determine whether the FEMP is within the DOE effective dose limit of 100 mrem per year from all exposure pathways (excluding radon), estimates of dose due to direct radiation are combined with airborne emissions to estimate the total dose to the maximally exposed individual. This estimate reflects the incremental dose above background that is attributable to the FEMP.

The DOE limits for radon and its decay products in air are provided in terms of concentrations rather than dose limits and are addressed independently of the all-pathway dose limit. A concentration-based limit is used because dose calculations associated with radon and its decay products are highly sensitive to input parameters which are difficult to confirm with environmental measurements. Nonetheless, dose estimates for radon have been included in this section in response to FEMP stakeholders' interests in radon exposures. A number of different radon dose calculations are presented in this section to demonstrate the variation of radon doses based on each method of calculation. The radon dose estimates in this section can also be compared with radon dose estimates presented in previous annual site environmental reports and other radon dose studies (i.e., Fernald Dosimetry Reconstruction Project [RAC 1996]).

Estimated Dose from Airborne Emissions

The estimated dose from 2001 airborne emissions was calculated from annual average radionuclide concentrations measured at the 18 IEMP air particulate monitoring locations (two background and 16 fenceline locations [refer to Figure 5-1 in Chapter 5 for the location of the air particulate monitoring locations]). Annual average background concentrations were subtracted from the fenceline concentrations in order to account for the natural occurrence of airborne radionuclides. Dose estimates were determined by converting the net annual average radionuclide concentrations measured at each fenceline monitoring location to doses using values listed in 40 Code of Federal Regulations 61 (NESHAP) Subpart H, Appendix E, Table 2.

The maximum effective dose at the fenceline from 2001 airborne emissions was estimated to be 0.8 mrem per year and occurred at AMS-3 along the eastern fenceline of the site. The dose estimate is based on the conservative assumption that a person remains outdoors at the AMS-3 location for 100 percent of the time during the year. Recognizing that the nearest residence is located approximately 1,500 feet (450 meters) downwind from AMS-3 (east-southeast from the site), the actual dose received by this receptor would be substantially lower than 0.8 mrem per year.

The maximum fenceline dose of 0.8 mrem in 2001 is lower than the maximum fenceline dose of 1.1 mrem in 2000 and well below the NESHAP annual limit of 10 mrem. The decrease is attributable to increased emission control efforts from remediation activities associated with the Waste Pits Remedial Action Project, on-site disposal facility and its associated material transfer area, and the Plant 6 Decontamination and Dismantlement Project. Fugitive emissions from the Waste Pits Remedial Action Project waste processing activities, and specifically thorium-230 emissions, were the major contributors to the maximum fenceline dose in 2001.

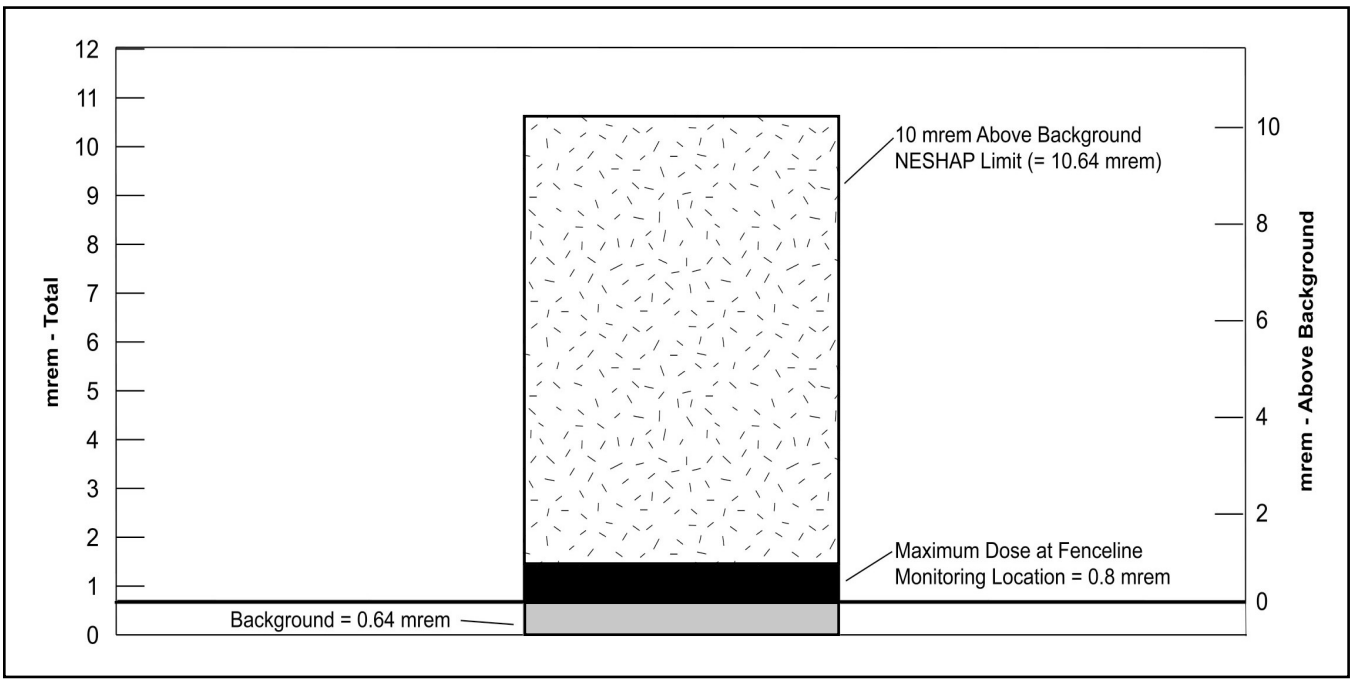

Figure 6-1. Comparison of 2001 Air Pathway Doses and Allowable Limits

Figure 6-1 provides a comparison between the air pathway doses at the average background and maximum fenceline locations with the annual NESHAP limit of 10 mrem. The average background and maximum fenceline doses shown in Figure 6-1 are primarily attributable to the airborne concentration of uranium, thorium and radium and exclude contributions from radon (dose from radon is excluded from the annual NESHAP limit of 10 mrem). The maximum air pathway dose of 0.8 mrem above background, (which is in addition to the average air pathway background dose of 0.64 mrem) is 8 percent of the annual NESHAP limit. The estimated dose for each radionuclide from airborne emissions measured at each fenceline air monitor is provided in Appendix D of this report.

Direct Radiation Dose

Direct radiation dose is the result of gamma and x-ray radiation emitted from radionuclides stored on site. The largest source of direct radiation at the FEMP is the waste stored in the K-65 Silos. As the waste in the silos undergoes radioactive decay, gamma rays and x-rays are emitted. Direct radiation from the decay of radon progeny in the silo headspace contributes a major fraction of the direct radiation from the K-65 Silos. As the headspace radon concentrations have increased over the last nine years (1993 through 2001), the direct radiation from the silos has also increased. Direct radiation levels at the K-65 Silos and site fenceline are monitored by a network of environmental TLDs. Chapter 5 provides a description of the direct radiation monitoring.

The direct radiation dose for 2001 at the fenceline was estimated using the highest dose from the fenceline monitoring locations and subtracting the average dose measured at background TLD locations. This method provides a conservative estimate of direct radiation dose and measures the impact of increasing radiation levels near the silos and the fenceline due to increasing levels of radon and associated decay products in the silo headspace (refer to Chapter 5). From the data in Table 5-3, the maximum fenceline measurement was 90 mrem per year and occurred at TLD location 16. The average background dose from the six background TLD locations was 72 mrem. The difference in these values (18 mrem) is the estimated fenceline direct radiation dose for a hypothetical individual who stands at the fenceline, specifically TLD location 16, for the entire year.

In accordance with DOE Order 5400.5, Radiation Protection of the Public and the Environment, which requires that realistic exposure conditions be used for conducting dose evaluations, an estimate of direct radiation dose was calculated for a residence nearest the K-65 Silos. This dose was estimated by using the net fenceline TLD measurement at TLD 16 and accounting for the distance between the fenceline TLD location and the residence (approximately 326 feet [99 meters]) which would lower the direct radiation dose to approximately 11.5 mrem. This estimate remains extremely conservative in that it assumes a resident at this location is present 24 hours per day for a full year and does not account for shielding provided by the structure of the house.

Total of Doses to Maximally Exposed Individual

The maximally exposed individual is the member of the public who receives the highest estimated effective dose equivalent based on the sum of the individual pathway doses. As shown in Table 6-1, the 2001 dose to the maximally exposed individual is the sum of the estimated doses from direct radiation dose and airborne emissions (excluding radon). The conservative assumptions used throughout the dose calculation process ensure that the dose to the maximally exposed individual is the maximum possible dose any member of the public could receive. The 2001 dose to the maximally exposed individual is estimated to be 11.7 mrem. The contributions to this all-pathway dose are:

- 11.5 mrem from direct radiation to an off-site receptor located near the western fenceline of the FEMP

- 0.2 mrem from air inhalation dose, as measured at AMS-6, to an off-site receptor located near the western fenceline of the FEMP.

This estimate represents the incremental dose above background attributable to the FEMP, exclusive of the dose received from radon. Figure 6-2 provides a comparison between the average background radiation dose at background (72.6 mrem) and the all-pathway dose to the maximally exposed individual (11.7 mrem). Figure 6-2 also provides a graphical comparison to the annual DOE all-pathway limit of 100 mrem.

TABLE 6-1
DOSE TO MAXIMALLY EXPOSED INDIVIDUAL

Pathway	Dose Attributable to the FEMP	Applicable Limit
Air		
Airborne emissions at AMS-6 (excluding radon)	0.2 mrem	10 mrem (air pathway)
Direct radiation	11.5 mrem	100 mrem (total of all pathways)
Maximally exposed individual	11.7 mrem	100 mrem (total of all pathways)

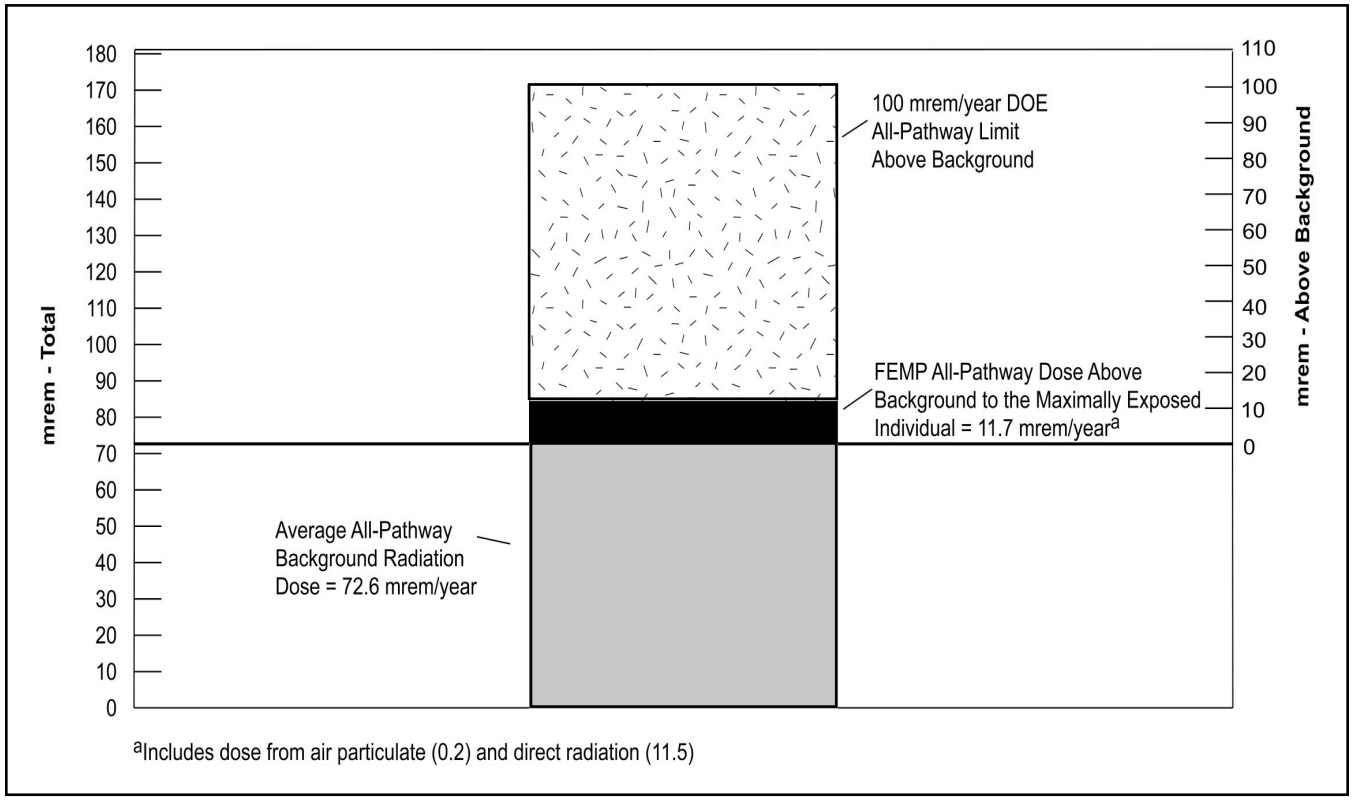

Figure 6-2. Comparison of 2001 All Pathway Doses and Allowable Limits

Significance of Estimated Radiation Doses for 2001

One method of evaluating the significance of the estimated doses is to compare them with doses received from background radiation. Background radiation yields approximately 100 mrem per year from natural sources, excluding radon. For example, the dose received each year from cosmic and terrestrial background radiation contributes approximately 26 and 28 mrem, respectively. In addition, the background radiation dose will vary in different parts of the country. Living in the Cincinnati area contributes an annual dose of approximately 110 mrem, whereas living in the Denver area would contribute approximately 125 mrem from background radiation (U.S. National Academy of Science 1980) (National Council on Radiation Protection and Measurements 1987). Comparing the maximally exposed individual dose to the background dose demonstrates that, even with the conservative estimates, the dose to a member of the public (nearest resident) from the FEMP is much less than the natural background radiation dose. Although the estimated dose will be received in addition to the background dose, this comparison provides a basis for evaluating the significance of the estimated doses.

Another method of determining the significance of the estimated doses is to compare them with dose limits developed to protect the public. The International Commission on Radiological Protection (ICRP) has recommended that members of the public receive no more than 100 mrem per year above background. As a result of this recommendation, DOE has incorporated 100 mrem per year above background as the limit in DOE Order 5400.5, Radiation Protection of the Public and the Environment. The sum of all estimated doses from FEMP operations for 2001 (11.7 mrem) was significantly below this limit.

Estimated Dose from Radon

Radon in the air decays to produce more radioactive material, known as daughter products. Airborne daughter products attach to dust particles that may be inhaled and deposited within the lungs. As the daughter products decay, they emit electrostatically charged particles (alpha and beta particles) that may damage sensitive tissues of the lung. For exposures to radon and its daughters, the target organ for the radiation dose is the lung.

Radon dose estimate methodologies from the ICRP and National Council on Radiation Protection (NCRP) have been revised and updated over the years with the primary effect being a decrease in the estimated health damage (detriment) per unit of radiation exposure. The revisions were based on re-evaluations of studies examining the detrimental health effects (i.e., epidemiological studies) on highly exposed worker populations (i.e., uranium miners). Therefore, radon dose estimates were generated for this report using the following four different calculation methods:

- Working level-month determination
  Historically, radon daughter exposure rates have been measured in the units of working levels, a measure of the activity concentration of the radon daughters in air. A working level is approximately equivalent to a radioactivity concentration of 100 pCi/L of radon in 100 percent equilibrium with its daughters. An individual exposure is then determined by multiplying the working level by the number of 170-hour periods (i.e., a work month) at that level, yielding the exposure unit working level-month. Working level-months of exposure are provided because all dose conversion factors and detriment coefficients used in estimating a dose from radon and its daughters are derived from this fundamental unit.

- NCRP 78 report
  This document, in part, provides equations for converting exposure resulting from inhalation of radon daughter products to an equivalent lung dose. This method considered the whole lung as the target organ for the radiation exposure. A number of dose conversion factors and assumptions are utilized to equate the lung dose to a whole body radiation dose (i.e., effective dose equivalent). Equations from this report were utilized in previous annual site environmental reports and are presented here for direct comparison to previous years' estimates.

- ICRP 66 tissue weighting factor modification to NCRP 78 equation
  ICRP 66 introduced a specific tissue-weighting factor representing the localized radiation exposure to the bronchial epithelium (a specific region of the lung thought to be the source for lung cancer) from inhalation of radon daughter products. Using the NCRP 78 equations, this new weighting factor results in a reduction of the effective dose by a factor of three. Incorporation of factors from this report allows comparison to dose estimates provided in the Fernald Dosimetry Reconstruction Project performed by Radiological Assessments Corporation under contract with the Centers for Disease Control.

- ICRP 65 report
  This report suggests the use of detriment coefficients for estimating dose from exposure to radon daughter products. These detriment coefficients are based on epidemiological studies of the lung cancer rates among uranium miners. The new coefficients result in a dose conversion factor of approximately 500 mrem per working level-month. This report was released in 1994 and represents a more recent methodology for calculating radon dose.

Table 6-2 presents the 2001 radon dose estimates, and includes concentration values for fenceline and background locations, as well as DOE radon concentration limit values. Estimated working level-month exposures are given for each concentration value, as well as effective dose equivalents utilizing the NCRP 78, ICRP 66, and ICRP 65 methods. Doses were calculated from annual average continuous radon data (assuming the suggested environmental radon daughter product equilibrium concentration of 70 percent). All dose estimates are for a hypothetical maximally exposed reference man of average body size and breathing rate who continuously breathed air at the FEMP fenceline while engaged in light, physical activity 24 hours a day for the entire year. This exposure scenario is highly conservative, but suggests that in using the ICRP 65 methodology the dose from FEMP radon emissions at the fenceline monitor nearest a public receptor is 18 mrem per year above background.

Although there are no regulatory limits for dose from radon and its daughters, the radon concentration limits imposed by DOE Order 5400.5 provide a benchmark for evaluating the estimated doses from radon at the FEMP boundary. In DOE Order 5400.5, the annual average radon concentration limit at the facility boundary is 3 pCi/L above background. Using the ICRP 65 methodology, a concentration of 3 pCi/L equates to an effective dose equivalent of 547 mrem. As presented in Table 6-2, the maximum measured radon concentration and corresponding dose at the FEMP boundary are well below the limits associated with DOE Order 5400.5.

TABLE 6-2
2001 RADON DOSE ESTIMATE[a]

Location	Radon Concentration (pCi/L)	Exposure in Working Level-Months (WLM)	NCRP 78 Effective Dose Equivalent Equation		ICRP 65 Effective Dose Equivalent (mrem)[d]
			(mrem)[b]	(mrem)[c]	
Average Background	0.2	0.072	144	48	36
Fenceline Monitor Nearest Receptor (net, above background)	0.1	0.036	72	24	18
Maximum Fenceline (net, above background)	0.2	0.072	144	48	36
DOE Order 5400.5 Limit (net, above background)	3	1.08	2,106	720	547

[a]Assuming the suggested environmental radon daughter product equilibrium concentration of 70 percent
[b]NCRP 78 suggests whole lung tissue weighting factor of 0.12
[c]NCRP 78 calculation using the ICRP 66 bronchial epithelium weighting factor of 0.04
[d]Utilizing the dose conversion factor for the maximally-exposed reference man